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INCREASING THE POTATO CROP BY SPRAYING

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INSECTS AND DISEASES reduce the potato crop of this country each year more than 100,000,000 bushels, according to careful estimates. This loss would be much greater if potato growers did not spray their crops, although spraying is not practiced as widely or as thoroughly as it should be. All growers should endeavor to increase their yield per acre by preventing these losses from insects and diseases.

This bulletin tells how to control the Colorado potato beetle and late-blight (the worst two enemies of the potato), blister beetles, flea-beetles, cutworms and other caterpillars, leafhoppers, aphids or plant-lice, and early-blight and other foliage diseases.

For most of these insects and for the diseases discussed in this bulletin, spraying with Bordeaux mixture and lead arsenate is recommended, but for aphids or plant-lice, contact sprays, such as nicotine sulphate and emulsions, are the best. For blight, Bordeaux mixture is an efficient means of control. Directions for preparing and applying these sprays are given. Other methods of control described in this bulletin, such as jarring and driving, together with crop rotation and clean cultural methods, also help considerably in protecting the crop.

The best spraying outfits available should be procured.

This bulletin is a revision of Farmers' Bulletin 863, which it supersedes.

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P.A.B

INCREASING THE POTATO CROP BY SPRAYING.

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IN THE year 1920 the average yield of potatoes in the United States was estimated at 110 bushels per acre. In the following year the estimated average yield decreased to about 91 bushels per acre. Two of the causes of low crop yield are insects and diseases. It has been estimated that the total loss from potato diseases and insects in the United States frequently is as much as 100,000,000 bushels. In New York in 1912 the potato crop was reduced 20,000,000 bushels as a result of late-blight.

The more important insects and diseases of the potato are discussed in the following pages, with methods of combating them.

THE COLORADO POTATO BEETLE.[1]

Injury by the Colorado potato beetle is the work of both the "slugs" (young, or larvæ) and the beetles, or adults. The beetles,

[1] *Leptinotarsa decemlineata* Say.

NOTE.—The insects treated in this bulletin are all leaf-feeders. Some of those which feed in the stalks and tubers, viz, the potato stalk-weevil, the common stalk-borer, the potato tuber-moth, white grubs, and wireworms, also are very injurious in certain areas, but these are controlled by methods different from those used against the leaf-feeders, and they will be treated in a separate publication. The diseases treated herein are those affecting the foliage and are preventable, in the main, by spraying. Other potato diseases affecting the tubers or controllable by seed selection are treated in Farmers' Bulletin 1367, Control of Potato-tuber Diseases, and in a forthcoming Farmers' Bulletin on seed-borne diseases of the potato.

after they pass the winter, appear usually at about the same time as the potato plants, lay their eggs, continue feeding, and frequently destroy unprotected plantings, especially those grown for garden purposes. When the larvæ begin to grow they usually finish the work begun by the beetles, so that in a very short time, or by the time the larvæ are nearly full grown, very little of the potato plants remains except denuded or bare stems and dry and black foliage. After potato fields have become defoliated the beetles and larvæ attack eggplant and other plants of the potato family.

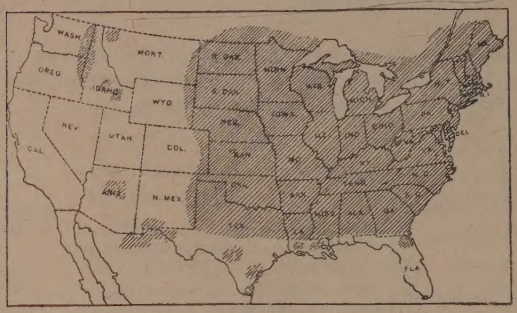

FIG. 1.—Map showing, by shaded areas, approximate distribution of the Colorado potato beetle.

The distribution of the Colorado potato beetle (fig. 1) covers practically the entire United States from the Great Plains eastward to the Atlantic coast, excepting the extreme southern parts of Florida, Alabama, Mississippi, and Louisiana. In Texas it occurs in the tropical region bordering the Gulf of Mexico. It also occurs in more restricted parts of Washington, Oregon, Idaho, Arizona, Montana, Wyoming, Colorado, and New Mexico. In a few of these States it is present, but not as a pest—for example, in some regions of Colorado, where it feeds on a wild plant belonging to the potato family. It is constantly extending its territory as a pest.

FIG. 2.—Colorado potato beetle: *a*, Beetle; *b*, larva, or "slug"; *c*, pupa. Enlarged.

This potato beetle is well known to all growers of potatoes. The beetle is robust, yellow, and its wing-covers are ornamented with 10 black lines (fig. 2, *a;* fig. 3, *a*). It is three-eighths of an inch long. The "slugs" (young, or larvæ; fig. 2, *b;* fig. 3, *c*, *c*, *d*, *d*) are dark red when first hatched, becoming paler with larger growth. They are slimy, soft in texture, and of disgusting appearance. The pupa, or resting stage, is shown at *c* in Figure 2. The eggs (fig. 3, *b*, *b*) are orange colored and are deposited in masses.

The Colorado potato beetle feeds on practically all plants of the potato family, attacking potato, eggplant, tomato, ground cherry, and Jimson weed, besides other weeds of this family.

In the more northern range of this insect there is probably only one generation a year, or, exceptionally, two generations. Farther southward three more or less complete generations occur. This insect

FIG. 3.—Section of potato plant showing Colorado potato beetle at work: *a*, Beetle; *b, b*, egg masses; *c, c*, half-grown larvæ; *d, d*, mature larvæ. Somewhat enlarged.

pest passes the winter in the beetle stage, usually from 3 or 4 to 8 or 10 inches underground.

The beetles appear in the spring, and with the first warm days may be seen in flight. As soon as the female can reach suitable plants after feeding she begins to lay her eggs. A single female is capable of producing between 1,800 and 1,900 eggs. Normally all

the eggs hatch, and the entire life cycle from egg to egg may be passed in midsummer in a high temperature in five or six weeks. The possible progeny, therefore, is enormous.

Were it not for the fact that numerous species of insects and higher animals destroy large numbers of the beetles and "slugs" annually, the pest would be much more abundant than it is. (See fig. 4.) In addition to destruction by other insects, of which between 30 and 40 species have been observed actually to prey upon this pest, the bobwhite or quail, robin, crow, and several other birds either pick the beetles from the vines or dig them from the earth, and skunks, snakes, and toads frequently gorge on them. Domestic fowls, especially ducks and guinea fowl, also are of assistance in suppressing this pest.

FIG. 4.—A ladybird (*Hippodamia convergens*) which preys on the eggs of the Colorado potato beetle. Much enlarged.

HOW TO CONTROL THE COLORADO POTATO BEETLE.

The Colorado potato beetle may be controlled by proper treatment with certain arsenical sprays. (See figs. 5 and 6.) In the majority of cases, particularly in the Northern States, the combined treatment for diseases and insects outlined on a later page should be followed. The following materials and procedure are advised when this insect alone is to be combated.

ARSENATE OF LEAD.

As a spray for the potato beetle and similar pests, lead arsenate serves the same purpose as Paris green and is even more valuable.

Arsenate of lead has the following advantages over Paris green: (1) It contains less soluble arsenic, which is injurious to the foliage; (2) it is less harmful to young growing plants, and when applied in the proper manner and at the proper strength does not scorch them; (3) it adheres more strongly to the foliage; (4) it is less troublesome to prepare; and (5) it is of greater value than other arsenicals (except zinc arsenite and calcium arsenate) in that it leaves a white coating on the foliage, so that its presence or absence can be determined readily after spraying.

The formula is as follows:

Arsenate of lead (powder)	pound	1
Water or Bordeaux mixture	gallons	25

If the paste form of arsenate of lead is used, 2 pounds to 25 gallons of the liquid is the proper proportion.

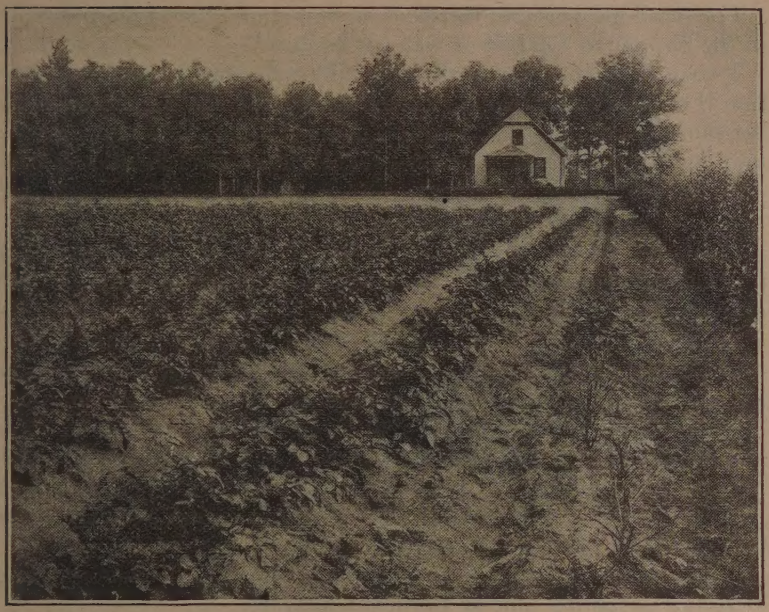

FIG. 5.—Field of potatoes showing outside row unsprayed in comparison with the remainder of the plat sprayed for the Colorado potato beetle with Paris green, one-half pound to 50 gallons of water.

FIG. 6.—In foreground, potato plants not sprayed for the Colorado potato beetle; in background, sprayed potato plants.

For small gardens two-thirds of an ounce, or 10 level teaspoonfuls, of the powder to 1 gallon of water is used.

Two or three sprayings ordinarily will suffice for the spring generation if applied before the eggs are hatched, and about the same number should be employed for the second generation. One or two sprayings for the third generation, when it appears, also should be given.

CALCIUM ARSENATE.

Calcium arsenate, or arsenate of lime, is a valuable remedy for the Colorado potato beetle. Its composition is similar to that of lead arsenate, lime being the base instead of lead. It has a stronger arsenic content than lead arsenate, hence possesses greater killing power and is therefore much cheaper. It is prepared in the same manner for use against vegetable insects. A good quality of powdered calcium arsenate contains 40 to 44 per cent of arsenic oxide and should contain at least 40 per cent, about 1½ per cent of which may be water-soluble. Powdered calcium arsenate, 1 pound, is used in 50 gallons of water or fungicide. For garden use one-half ounce to 1 gallon of water is employed.

Calcium arsenate may be used in combination with other spraying material containing lime or Bordeaux mixture.

As a dust, calcium arsenate is successfully used against certain forms of pests [2] and should be perfectly effective against the Colorado potato beetle, blister beetles, and similar pests. It is best applied thoroughly mixed with from 5 to 10 times its weight of hydrated or air-slaked lime and so proportioned as to apply 3 to 4 pounds of the calcium arsenate to the acre.

A high-grade calcium arsenate 1 part, mixed with dusting sulphur 1 part, and hydrated lime 4 parts, is also satisfactory.

In gardens small dusters are useful. On large patches a knapsack type of bellows duster with a spout attached to a flexible hose is the best machine. The fan type of cotton or tobacco duster gives fair results if the discharge tube is turned sidewise so as to direct the dust into the foliage.

PARIS GREEN.

Although lead arsenate has come into general use against the Colorado potato beetle, Paris green has been for many years a standard insecticide for this pest.

Paris green spray is prepared by mixing the arsenical with water or Bordeaux mixture at the rate of 1 to 2 pounds of poison to 100 gallons of the mixture. When water alone is used quicklime in about the same proportion as the poison should be added to prevent scorch-

[2] Notably the cotton boll weevil and the Mexican bean beetle.

the potato plant and feed upon it and later produce vast numbers of minute spores or fruiting bodies. These are spread by wind and water to other plants, which may become infected and produce another crop of spores within five or six days. The tubers become infected by spores washed down through the soil from the blighted foliage or by contact with blighted tops when digging is being done.

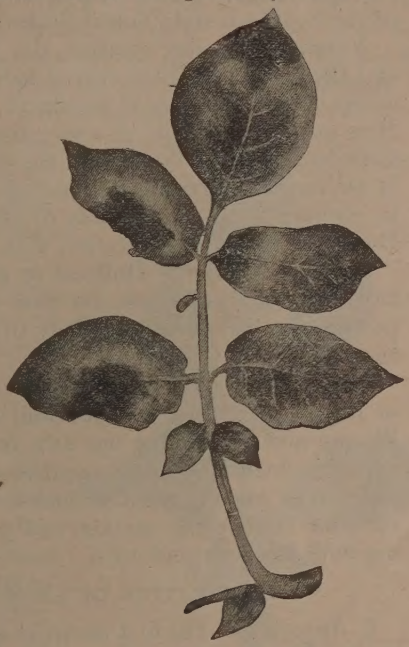

FIG. 18.—Potato late-blight.

FACTORS INFLUENCING LATE-BLIGHT.

The origin of the infection.— Late-blight does not occur in the soil. It overwinters in stored tubers. Potatoes with more or less dry rot are frequently planted, and some of them give rise to weak sprouts. The fungus grows up these shoots and produces spores on the above ground parts, which are carried to adjacent plants and start centers of infection. Such first cases of late-blight often are present in the fields two weeks or more before the disease becomes epidemic.

In preparing potatoes for planting it is important to reject seed potatoes affected with late-blight dry rot, as infected tubers often decay in the ground without germinating, but there is little hope of avoiding the disease by this precaution, since under favorable weather conditions blight is carried many miles in a short time. No method of treating seed potatoes to kill late-blight has been found practicable. Thorough spraying with Bordeaux mixture is the only preventive.

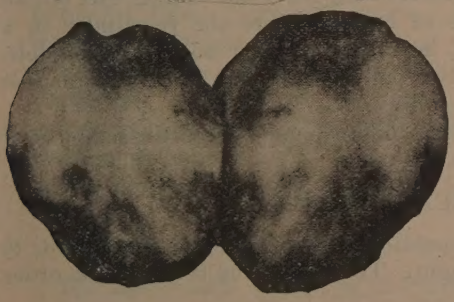

FIG. 19.—Late-blight tuber rot.

Temperature. — Late-blight spreads most rapidly when the daily mean temperature is 72° to 74° F., with abundant moisture. Weather which in the North is

designated as "warm and muggy" is therefore favorable to the rapid development of late-blight, whereas the hot summer weather of the Southern and Central States checks it completely.

Moisture.—In dry weather the production of spores is checked, and the disease ceases to spread because the spores can not germinate except in the presence of moisture. Dry foliage can not be infected. It is only when drops of water from rain or heavy dews stand for some hours on the leaves that the disease can gain a foothold. This is an important point to remember in connection with spraying; it explains why all portions of the plant should be covered with Bordeaux and why protection with the spray before rain is needed.

Soil and location.—Hollows or low places in the fields, wherever moisture remains longest, are most likely to develop late-blight, and potatoes on clay soils are likely to suffer more from rot than those on sandy soil.

Varieties.—Partially resistant varieties of potatoes have been bred in Europe, but these are not well adapted to American conditions. We are now developing our own resistant strains, but at present no variety which meets the requirements for a standard commercial sort can be recommended as disease resistant. Select the best variety for your locality and market, and protect from late-blight by spraying with Bordeaux mixture.

PREVENTION OF LATE-BLIGHT TUBER ROT.

1. *Spraying.*—The first essential is to spray, as recommended under the heading "Combined treatment for diseases and insects."

2. *Date of digging.*—It is unwise to dig potatoes when the first blight appears. The immature tubers are not in condition to keep well and they become infected by contact with the tops while being harvested. Consequently, the potatoes should not be dug until a week or more after the tops are entirely dead.

3. *Sorting and storage.*—Immediately after harvesting, sort out all potatoes showing any trace of rot and store the remainder in a dry cellar or storage house, kept cool, as near 36° F. as possible. Dry rot will not develop at this temperature, but in a warm place it will be spread from tuber to tuber.

No treatment with lime, formaldehyde, or other disinfectant is of any value against late-blight dry rot.

OTHER DISEASES.

Several other diseases of potato foliage should be mentioned, to avoid confusion with late-blight. They are listed below in the order of their appearance.

SUNSCALD.

Young potato plants that have made a rapid growth during cool and moist weather may suffer from hot, bright weather. The leaves droop and wilt, and some are killed, but the plants usually recover.

HOPPERBURN AND TIPBURN.

A very prevalent and serious injury to potato foliage, due to the attack of the potato leafhopper, is manifested by a browning of the leaf margins, which become dead and dry, as illustrated in Figure 20. The greater part of the disease hitherto called tipburn, especially in the Central States, is now known to be hopperburn.

A tipburn due to protracted hot and dry weather, complicated by flea-beetle injury and early-blight, occurs as a minor trouble independent of leafhopper injury.

The best protection against both hopperburn and tipburn is thorough spraying with Bordeaux mixture.

FIG. 20.—Potato hopperburn.

EARLY-BLIGHT.

Early-blight is a fungous disease which appears in the North before the late-blight. In the South, however, it is more common on the fall crop. It is likely to occur in all sections of the country.

This disease is marked by the appearance of nearly black spots on the otherwise green leaves. As these enlarge they are marked by faint concentric rings. (See fig. 21.) Eventually the leaves yellow and die, and in cases of severe attacks the tuber yield may be reduced 10 to 25 per cent.

Early-blight attacks weakened plants and is worst upon light soils, not well adapted, by fertility and moisture supply, to potato growing. When conditions favor, it becomes widespread.

The combined treatment advised below includes Bordeaux mixture for early-blight.

ARSENICAL POISONING.

The use of large quantities of Paris green in water for insect control results in a burning of the leaves, often in concentric spots centering at flea-beetle punctures, somewhat resembling early-blight. When the arsenical is combined with Bordeaux mixture this injury is avoided.

COMBINED TREATMENT FOR DISEASES AND INSECTS.

Watch the young plants closely and spray with Bordeaux mixture and arsenate of lead as soon as the first evidence of the Colorado potato beetle or of flea-beetles is noted.

Repeat this application every 10 to 14 days to keep all of the new foliage protected. If no insects are present and the weather is dry, the intervals between sprayings may be lengthened.

FIG. 21.—Potato early-blight.

As the late-blight season approaches, which in the North usually is after the middle of July, a protective spraying should be given and the weather watched more closely, for if continuous showers occur, with a mean temperature of 72° to 74° F., spraying every five to seven days will be necessary.

A system for reporting the appearance and progress of late-blight should be organized in order that potato growers may be warned when to increase their efforts.

VALUE OF SPRAYING.

Throughout most of the late-blight area shaded on the map (fig. 17) it pays to spray potatoes with Bordeaux and arsenicals, whether blight develops or not. With few exceptions, large gains in yield are due to protection from Colorado beetles, flea-beetles, grasshoppers, early-blight, tipburn, etc. This fact has been established by extensive experiments which have been conducted in New York and Vermont. During a 10-year period, at different experiment stations

ing. For the proper mixing and application of this spray a bucket pump or knapsack sprayer of good quality is sufficient for use in small gardens, but on a larger scale a potato sprayer drawn by horses or mules is necessary. A small quantity of water is added to the Paris green to form a thin paste before the bulk of water is added, and the mixture should then be thoroughly blended by churning by means of a force pump or sprayer. The mixture is a mechanical one and the arsenical will soon sink to the bottom. To avoid this it must be stirred constantly while being applied. It is advisable in many cases to apply it in Bordeaux mixture, as this is a valuable insect repellent as well as a standard fungicide and also neutralizes any free arsenic present, thus preventing burning of the foliage.

Paris green may also be used dry, mixed with 10 to 20 parts of cheap dry flour, sifted land plaster, or fresh air-slaked lime. This remedy affords best results early in the season on young plants. It should be applied preferably when the dew is on and by means of powder guns or bellows so as to cover the plants and leave as little untreated surface as possible for food for the first-appearing insects.

Precaution to prevent poisoning.—Arsenicals should be labeled properly and the word POISON should appear on the package. It is best to keep poisonous substances under lock and key and where children can not reach them.

Utensils employed in the preparation of arsenate of lead should be cleaned thoroughly after use.

OTHER REMEDIES.

Jarring is of value early in the season. It is performed usually by brushing the beetles and "slugs" into large shallow milk pans or similar receptacles containing a little water on which a thin scum of kerosene is floating. Egg masses should be clipped off whenever observed and destroyed promptly.

Fall and spring plowing, while valuable for most insects which pass the winter in the ground, is less valuable for the potato beetle, because hibernation takes place far under the surface, and very deep plowing would be necessary.

Hand picking is effective early in the season, but later is too slow and laborious.

BLISTER BEETLES.

The potato is subject to injurious attack by blister beetles of several forms. These beetles are slender, comparatively soft bodied, and variously colored. All are general feeders, and a large proportion of them prefer potatoes to other foods. One of the commonest of these is the black blister beetle (fig. 7).[3] It appears at about the

[3] *Epicauta pennsylvanica* DeG.

time of the flowering of wild aster and goldenrod, and is known also as the "aster bug." Besides potato, it attacks beans, peas, cabbages, and various other plants. Other common species are the margined [4] and the striped [5] blister beetles, shown in Figures 8 and 9. These insects are gregarious and migratory in habit, feeding most voraciously, running rapidly, and flying from time to time. Frequently they descend on a crop and ruin it in a few days, eating both foliage and stems. They appear at different times, according to temperature, usually being most abundant from July to September.

CONTROL METHODS FOR BLISTER BEETLES.

Arsenate of lead is the best remedy for blister beetles. It is prepared and applied as directed for the Colorado potato beetle. In addition, in some portions of the West a line of boys and men go slowly through infested fields and drive the beetles ahead of them by short

FIG. 7.—Black blister beetle: Adult. Enlarged.

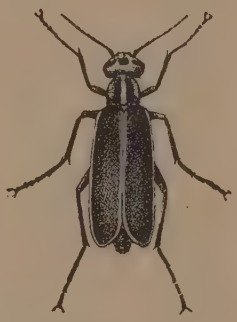

FIG. 8.—Margined blister beetle: Adult. Enlarged.

FIG. 9.—Striped blister beetle: Adult. Enlarged.

flights or running until they alight or come to rest in windrows of hay, straw, or other dry material, which previously has been prepared along the leeward side of the field. When the beetles take refuge in such a windrow it is burned promptly. This procedure has been followed with success.

Prompt application of remedies at the very outset of attack is necessary to save the crop.

FLEA-BEETLES.

The potato is attacked every year by flea-beetles, some of which are specific enemies of the crops of the potato family. Flea-beetles begin their work early in the season. The beetles riddle the leaves of young and tender plants with punctures, causing the leaves to die, thus depleting the vitality of the plant; and the larvæ, or young,

[4] *Epicauta marginata* Fab. [5] *Epicauta vittata* Fab.

feed at and injure the roots. These insects, a little larger than a flea, derive their common name from their small size and from the fact that their powerful hind legs enable them to take long leaps.

The most important of these insects is the potato flea-beetle [6] (fig. 10). This species occurs practically throughout the potato-growing regions of the country from Canada and New England to the Gulf region and in some districts in California. The most severe injury, however, is done in the North. The larva is the cause of "pimply" potatoes, which bring a lower price in the market, sometimes 5 cents a bushel less than the regular price. Eggplant, tomato, and tobacco also are attacked, and when this insect is numerous it sometimes attacks other plants. Eggs are laid early in May or June, and the life cycle may be completed in midsummer in about 35 days.

During recent years this species has shown a great fondness for tomato, and during the spring and summer of 1917, from April 19 to about the middle of July, injury was widespread. In the case of the tomato, plants were sometimes destroyed by defoliation when potatoes also were present. The aggregate of attack showed injury about equal on these two crops.

FIG. 10.—Potato flea-beetle: Adult. Does much injury to young plants. Actual length shown by line at right.

FIG. 11.—Eggplant flea-beetle, an insect which also attacks potato: Adult. Greatly enlarged.

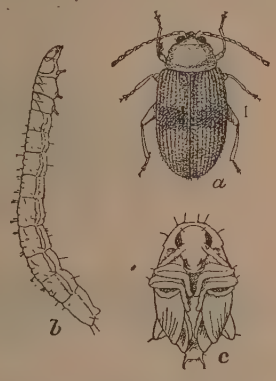

FIG. 12.—Tobacco flea-beetle, an insect which also attacks potato: *a*, Adult, or beetle; *b*, larva, side view; *c*, pupa, from below.

The eggplant flea-beetle [7] (fig. 11) and the tobacco flea-beetle [8] (fig. 12) also attack potato, but each is more common on the plant from which its English name is derived.

CONTROL METHODS FOR FLEA-BEETLES ON POTATO.

When potatoes are sprayed with lead arsenate for the Colorado potato beetle or with Bordeaux mixture for diseases, these beetles are repelled to a considerable extent. Because of their active jumping and flying habits they are not likely to remain on the plants during spraying, and are not poisoned to any extent, but they do not

[6] *Epitrix cucumeris* Harr. [7] *Epitrix fuscula* Cr. [8] *Epitrix parvula* Fab.

attack foliage that has been covered properly with either spray material.

Although the subject of exhaustive research for many years, a perfectly efficient remedy for the potato flea-beetle has not been found.

All wild plants of the potato family should be pulled up or otherwise destroyed throughout the season in order that the insects may have no other breeding place.

CUTWORMS.

Cutworms frequently do considerable damage to potatoes early in the season and sometimes later. They feed chiefly at night and in the shade, cutting off young plants about even with the ground. A common species is the granulated cutworm.[9] (Fig. 13.)

The best remedy for cutworms is poisoned bait. To mix and apply this bait take a bushel of dry bran, add 1 pound of white arsenic or Paris green, and mix it thoroughly into a mash with 8 gallons of water, into which has been stirred 2 quarts of sorghum or other cheap molasses. This amount is sufficient for the treatment of about 4 or 5 acres of cultivated crops. After the mash has stood for several hours, scatter it, in lumps about the size of a marble, over the fields where the injury is beginning to appear and about the bases of the plants attacked. Apply the bait late in the day, so as to place the poison about the plants before night, which is the time when the cutworms are active. Apply a second time if necessary. If this mash is made up with less water it may be applied with a grain or fertilizer drill to good advantage.[10]

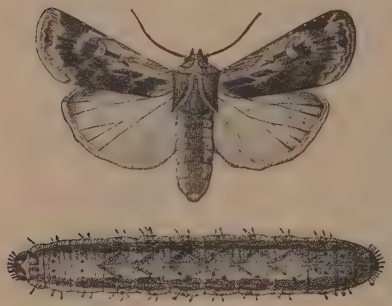

FIG. 13.—Granulated cutworm, an injurious potato insect: Moth above; cutworm, or larva, below. Somewhat enlarged.

Caution.—Arsenicals are deadly poisons and should be handled with great care. Keep children, livestock, and poultry away from this bait.

THE POTATO LEAFHOPPER.[11]

The potato leafhopper (fig. 14), a slender pale-green sucking insect, less than one-eighth inch long, the cause of a disease known as "hopperburn," is one of the worst leafhopper pests. It seriously injures numbers of cultivated plants, the principal ones being potato,

[9] *Feltia annexa* Treit.

[10] Additional information with regard to cutworms may be obtained upon application to the Bureau of Entomology, U. S. Department of Agriculture.

[11] *Empoasca mali* LeB.

beans (on which it also causes "hopperburn"), sugar beet, hemp, apple, raspberry, and cowpea.

Although a native insect of wide distribution, this leafhopper did not attract especial attention until 1914, when it was reported from Pennsylvania and New York as causing a "blight" because of the blighted appearance of the injured leaves. Losses caused to the grower of potatoes from the ravages of this pest, including the accompanying "hopperburn," are reported to be second only to those caused by the Colorado potato beetle. Indeed, in some years when the leafhopper and "hopperburn" abound, the combined loss may even take first rank in certain regions among all potato insects and diseases. The extent of injury fluctuates from year to year, but appears to be greatly on the increase.

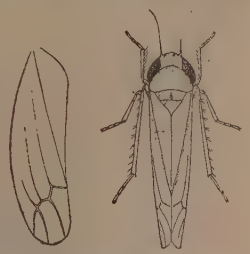

FIG. 14.—Potato leafhopper: At right, adult insect; at left, wing showing venation. Much enlarged.

The potato leafhopper is generally distributed throughout the United States and occurs in Canada and Mexico. The greatest losses incurred from its attack are in the Northern and Central States, from New York to Montana and southward in Ohio, Illinois, and Kansas.

METHODS FOR CONTROLLING THE POTATO LEAFHOPPER.

The potato leafhopper may be controlled and the "hopperburn" held in abeyance by timely and proper applications of Bordeaux mixture. The potato yield is greatly increased when this spray is employed. Bordeaux mixture, prepared according to the 4–4–50 formula (4 pounds copper sulphate and 4 pounds unslaked lime to 50 gallons of water), has proved a successful combination. Bordeaux mixture *must* be applied to the lower surface of the leaves, and the spraying must be thoroughly done so as to cover practically all foliage. It is also necessary to spray every row of plants from each side. A high pressure, at least 150 pounds, should be maintained in this application in order to cover the leaves with a fine mist, which gives a much better coating than a coarse spray. In abundant leafhopper years at least three applications must be made, the first as soon as the leafhoppers appear on the plants, the second about 10 days or two weeks later, and the third after an equal interval. Sometimes, in very hot, dry summers when leafhoppers occur in vast numbers, a fourth spraying is necessary, applied 10 days or two weeks after the third. The use of Bordeaux mixture on potatoes for the control of certain plant diseases and as a repellent for flea-beetles also acts strongly as a control of this pest.

For further information consult Farmers' Bulletin 1225, The Potato Leafhopper and Its Control.

APHIDS OR PLANT-LICE.

The potato crop suffers great losses during certain seasons, depending largely on atmospheric conditions, from two species of aphids or plant-lice, known, respectively, as the potato aphis [12] and the spinach aphis.[13]

These plant-lice act as disease transmitters, spreading the various types of mosaic disease, leaf-roll, and spindling tuber, by feeding on diseased plants and then migrate to healthy plants, carrying the infection with them. The reduction in yield of potatoes due to the spreading of disease by aphids is much greater than their direct injury by sucking the juices from the plants.

FIG. 15.—Potato aphis: Winged young-producing female. Highly magnified.

The potato aphis (fig. 15) is about as long as the potato leafhopper and is either pink or green, with long delicate wings, and honey tubes — tail-like processes which extend beyond the body. During the growing season it is somewhat closely restricted to potato, tomato, and related plants, but with the harvesting of those crops winged adults migrate to other plants, such as sweet potato and the cucurbits. It is widely distributed, but is more injurious in the northern tier of States.

Nicotine sulphate, a contact insecticide, has been used with success against the potato aphis, in the form of a spray. The standard formula adopted is as follows:

Nicotine sulphate, 40 per cent solution	pint	½
Fish-oil or other soap, dissolved	pounds	2
Water	gallons	50

A spray of nicotine sulphate is for several reasons preferable to kerosene emulsion or soap solutions and is easily prepared. Nicotine sulphate is marketed as a standard solution containing 40 per cent of nicotine, by weight. The soap acts as a "spreader" or

[12] *Macrosiphum solanifolii* Ashm. [13] *Myzus persicae* Sulz.

"sticker," and is added to the solution of nicotine sulphate and water. Common bar soap is satisfactory for ordinary purposes. For thorough control this solution should be applied in as fine a spray as possible. Most insects are reached more readily by a mist-like spray, but for sucking insects applications should be made with considerable pressure (150 pounds or more for the larger sprayers or large areas) so that every individual insect may be actually reached or hit by it.

For use in small gardens 1 teaspoonful of nicotine sulphate is used in 1 gallon of water, and to this a 1-inch cube of hard soap is added and the whole thoroughly mixed. If a larger quantity is needed, 1 fluid ounce of nicotine sulphate, 8 gallons of water, and ½ pound of soap are used. Directions are furnished on the covers of packages, and frequently instructions accompany them.

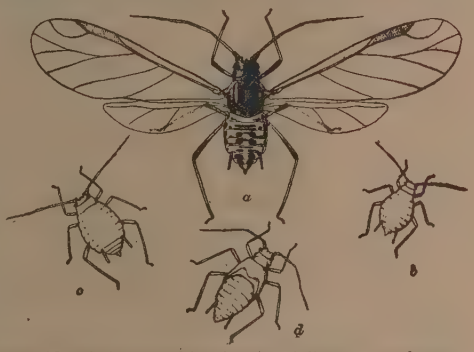

FIG. 16.—Spinach aphis, showing full-grown and young ones. Greatly enlarged.

The spinach aphis (fig. 16), also called "green fly," is more usually pale green, but occasionally pinkish, and is considerably smaller than the potato aphis. During the last decade of the nineteenth century it was extremely destructive to spinach in the tidewater Virginia region. It is what is termed "a general feeder" and is not in any way restricted to tomato and potato, but in recent years, beginning about 1917, it has caused more damage to those crops than to others. It is about equally well known as a pest on cabbage, beets, turnip, radish, celery, parsley, and lettuce, and is also of great importance as an enemy to ornamental plants, including those grown in greenhouses, and to fruit trees.

For the control of this pest about ⅜ pint of nicotine sulphate, 40 per cent solution, should be substituted in the formula given for the potato aphis.

LATE-BLIGHT AND ROT.

Late-blight is the most destructive potato disease. Originating in South America, it has spread to every potato country in the world and has destroyed crops to the extent of causing famine, as in Ireland in 1845.

In the United States late-blight is most common in the Northeastern States, as indicated on the map, Figure 17. In the shaded

areas in bad years 50 per cent of the crop in unsprayed fields may be destroyed. It occurs every year in northern New England, and usually visits New York and parts of the adjacent States; in wet seasons it extends as far west as Iowa and Minnesota. It occurs to some extent in the South Atlantic trucking sections from April to June and in the southern mountain region in autumn. The moist, cool climate of portions of the Pacific coast favors its development; but it is seldom or never found on the Great Plains, the Rocky Mountains, and other dry or hot parts of the country.

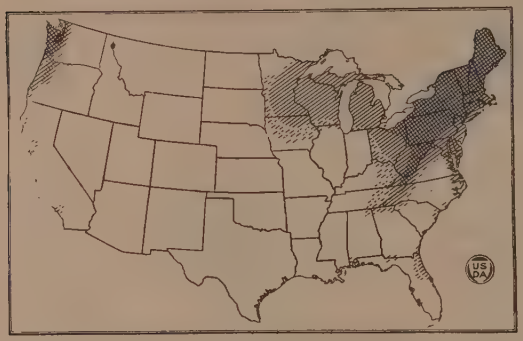

FIG. 17.—Map of the United States, showing the distribution of potato late-blight. The sections where the disease is the most prevalent are indicated by cross hatching. (Map prepared by the Plant Disease Survey, February 14, 1923.)

APPEARANCE OF LATE-BLIGHT AND ROT.

Late-blight develops after the blossom period and does its greatest damage toward the end of the growing season. It appears as purplish black or brownish black spots on the leaves, which, if examined when moist with dew or rain, show a delicate, powdery bloom on the underside. (See fig. 18.) The stems are attacked later, and the entire plant may be destroyed in a few days. If weather conditions favor the disease, fields go down within a few days as if swept by fire, and a foul odor characteristic of the disease is very perceptible.

The blighting of the foliage is followed by decay of the tubers, owing to spores of the blight fungus washed down through the soil from the foliage. If the soil is wet and heavy, there may be a rapid soft-rot caused principally by bacteria. The typical late-blight tuber injury, however, is a dry rot which develops in the field or after storage, as sunken brown spots near the outside of the tuber (fig. 19).

CAUSE OF LATE-BLIGHT.

Late-blight is due to a fungus[14] which lives as a parasite on the potato plant and some of its relatives.[15] This fungus is itself a plant formed of slender moldlike filaments (mycelium) which penetrate

[14] *Phytophthora infestans* (Mont.) DeBary.

[15] The potato late-blight fungus occasionally attacks the tomato, but most of the tomato late-blight is due to a specialized strain of the fungus.

in New York State, an average gain of 60 bushels per acre was secured. At the Vermont station, during a 20-year period, which involved all possible seasonal variations, an average gain of 105 bushels per acre, or 64 per cent over the unsprayed, resulted.

In addition, records taken from a business point of view on a series of experiments of a 9-year duration conducted by farmers under the direction of the New York State Experiment Station show large gains. The average cost of spraying, including materials, labor, and wear and tear on machinery, was $4.74 per acre. The 9-year average increase in yield due to spraying was 36 bushels per acre, making a net profit of $14.43 per acre. When these experiments were conducted the cost of materials was less than at the time this bulletin was written, but the increased product warrants an increased expenditure.

The value of such application of spray annually in regions not included in the blight area (fig. 17) is not so well established. Conditions in the Atlantic coastal region from New Jersey to Florida, for instance, are so different from those farther north that spraying can not be expected to give as large returns as in Maine or New York. In Florida there have been several years when late-blight has prevailed and spraying has been profitable. Here the argument for crop insurance is stronger and spray applications may be advised in number proportioned to the frequency of rain, but always thorough. In New Jersey also, as conditions begin to approach those of the North, gains from spraying may be expected. This is equally true in other regions of the United States, where blight occurs only in occasional years.

The foregoing figures show, however, that spraying is very profitable in districts where potato insects and leaf diseases annually take a big toll. The most successful growers in these districts, who wish to be insured against loss, practice thorough and consistent spraying, knowing that there will be large returns on their investment.

SPRAYING APPLIANCES.

For home gardens small hand sprayers of varying cost and efficiency are to be had.

For the farm potato patch, where from one-half acre to 3 acres are grown and where orchard trees or small fruits are to be sprayed, a barrel spray pump of good capacity is recommended. This hand pump is mounted on a 50-gallon barrel and carried on a homemade two-wheel cart or in a farm wagon.

If a cart is used the nozzle may be fastened to the back to spray four rows, but to do good work with this it is necessary, as with the lighter traction sprayers, to go over the field twice, the second time in the opposite direction.

More thorough work can be done by hand spraying if the pump is fitted with one or two lines of ½-inch hose, 25 feet long, ending in a 4-foot gas-pipe extension. This requires a man for each line and one to pump.

All commercial growers should provide themselves with the most effective traction sprayer they can secure. In these the pump is operated by a chain or gear drive from the wheels. It pays to get the best, as a high pressure of 120 to 150 pounds is needed for effective work. (See fig. 22.)

Gasoline engine power outfits do still better work and are suitable for large growers who desire a sprayer covering four or more rows with three nozzles per row and maintaining at least 200 pounds pressure.

FIG. 22.—Horse-driven power sprayer in use in a potato field.

A good nozzle is one of the most important parts of a spray outfit. The cyclone or eddy chamber type, of which the Vermorel is an example, is the best. The spray produced should be in the form of a fine mist covering every part of the plant.

For small vegetable gardens the common compressed-air sprayer employing a tank holding 3 or 4 gallons and provided with a pump for developing the air pressure is the most effective type. A cut-off in the spray rod retains the liquid in the tank until the desired pressure, as high as can be conveniently pumped, has been obtained. Then the liquid may be released as required. Such a machine costs $6 to $7 in galvanized iron, or $9 to $11 in brass. The latter is preferable, as it lasts longer and is less liable to corrosion by the chemicals used in spraying. (See fig. 23.)

HOW TO PREPARE BORDEAUX MIXTURE.

Bordeaux mixture is the fungicide that has greatest practical value against potato diseases. Lime-sulphur, powdered sulphur, copper lime dust, and other new mixtures that have come into use in orchards are injurious to the foliage, or weaker in fungicidal action, or both. The experiments to date show that for potatoes and other truck crops nothing has yet been found to replace the copper fungicides. The ingredients and method of preparation are as follows:

Copper sulphate, pounds	4
Quicklime, do	4
Water to make, gallons	50

Prepare the copper sulphate by suspending it in a gunny sack just below the surface of several gallons of water in a clean barrel. When the sulphate is dissolved, which requires three or four hours, remove the sack and stir into the barrel enough additional water to make exactly 25 gallons of the copper solution.

Prepare the lime by slaking it slowly and thoroughly in a clean barrel, strain, and add enough additional water to make exactly 25 gallons of lime milk. Stir thoroughly.

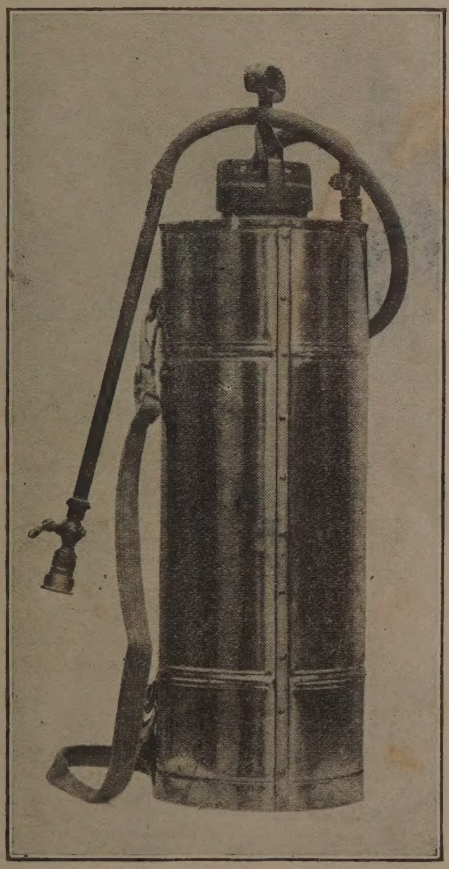

FIG. 23.—Compressed-air sprayer standing upright, showing hose, nozzle, and other attachments.

Pour the two ingredients together into another barrel or, better, directly into the spray tank, if it will hold 50 gallons. It is highly important to stir the mixture very thoroughly and to strain both ingredients before they are combined, as otherwise clogging of the spray nozzles might result. Use copper or bronze wire strainer of 18 meshes to the inch. Do not put copper sulphate or Bordeaux mixture into tin or iron

vessels; use wood or copper containers. Mix the Bordeaux solution as needed and apply at once. It is never so good after it has settled.

STOCK SOLUTIONS.

Everyone who uses Bordeaux mixture frequently and in quantity will find it convenient to keep on hand concentrated stock solutions of copper sulphate and of lime in separate containers. These stock solutions keep indefinitely if the water which evaporates is replaced. Build an elevated platform to hold the barrels. Some time before the day on which you wish to commence spraying, suspend 50 pounds of copper sulphate to dissolve in a 50-gallon barrel of water. Slake 50 pounds of lime in another barrel. Add water to make 50 gallons of milk. When Bordeaux mixture is needed, stir both stock thoroughly and take from each as many gallons as the formula calls for pounds. Dilute the copper sulphate in one barrel and the lime in another, each with half the water, and let the two streams run into the strainer of the spray tank. Add the arsenate of lead or other poison and stir well. Thorough agitation is important in making a good Bordeaux mixture.

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